SDC SOLENOID DESIGN NOTE 162

TITLE: Preliminary Study of the Aluminum Honeycomb Vacuum Shell

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ABSTRACT: This design note contains a study of aluminum honeycomb vacuum shell. An approximate approach is used to calculate the stiffness of honeycomb vacuum shell. By substituting this stiffness into the CGA equation and Roark's equation for a given collapsing pressure Pcr=30 (psi), the honeycomb facing and core thickness are obtained. Finally, the effective thickness is calculated based on the equivalent weight method. Result is agreed with Japanese calculation

COMPUTATIONAL METHOD:

(1). Stiffness of Honeycomb Structure

It is assumed that the core material provides no stiffness for the structure [1]. Therefore, the inertial moment of the honeycomb, I , with respect to the x axis can be calculated as

$$I = 2\left[\frac{t_f^3 \cdot b}{12} + t_f \cdot b \cdot \left(\frac{h}{2}\right)^2\right] \qquad (1)$$

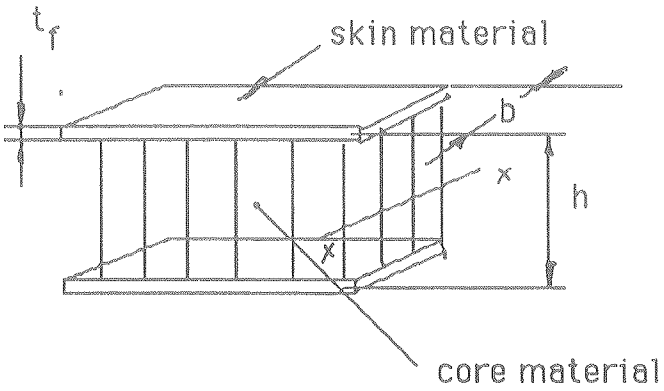


Figure 1 The structure of honeycomb

where t_f is the skin thickness, b is the width of honeycomb, and h is the distance between center lines of the skin. If t_f is very small compared with other dimensions, the cubic term of t_f may be neglected and Eq. 1 becomes

$$I = 2\left[t_f \cdot b \cdot \left(\frac{h}{2}\right)^2\right] = \frac{t_f \cdot h^2 \cdot b}{2} \qquad (2)$$

which is the same as the one given by HEXCEL TB124

(2) Stability Equation for the Collapse Pressure Pcr

The Compressed Gas Association For Cryogenic Liquid Cargo Tank Specification For Cryogenic liquid (CGA-341-1987) recommends a following equation to calculate the critical collapsing pressure Pcr

$$Pcr = \frac{2.6E(\frac{t}{D})^{2.5}}{\frac{L}{D} - 0.45(\frac{t}{D})^{0.5}} \qquad (3)$$

or as Fast [2] suggested

$$Pcr = \frac{2.6E(\frac{t}{D})^{2.5}}{(\frac{L}{D})} \qquad (4)$$

Roark [3] also gives an equation to calculate the collapse pressure for a given geometry as

$$Pcr = \frac{0.92E(\frac{t}{R})^{2.5}}{(\frac{L}{R})} \qquad (5)$$

The equation 5 is the same equation recommended by NASA [4] for iso-grid structures except there is a correlation, a knockdown, factor 0.7 is used. Equation. 4 and 5 can be rewrited as

$$Pcr = \alpha \cdot E \cdot I' \qquad (6)$$

where α is a constant, and EI' is the structure stiffness. Since the core material provides no stiffness for the structure as we assumed, the total stiffness of honeycomb can be calculated as

$$EI' = EI'_w - EI'_c = E(I'_w - I'_c) = E(t_w^{2.5} - t_c^{2.5}) \qquad (7)$$

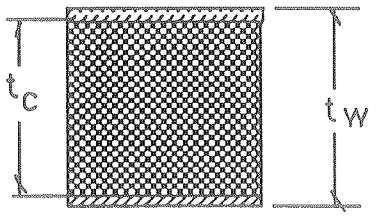


Figure 2 The honeycomb cross-sectional area

Substituting this Eq.7 into Eq. 4 and Eq 5, it gives two equations based on CGA and Roark's

$$Pcr = \frac{2.6E}{(\frac{L}{D})} \cdot \left[(\frac{t_w}{D})^{2.5} - (\frac{t_c}{D})^{2.5} \right] \qquad (8)$$

$$Pcr = \frac{0.92E}{(\frac{L}{R})} \left[(\frac{t_w}{R})^{2.5} - (\frac{t_c}{R})^{2.5} \right] \qquad (9)$$

For a Pcr=30 (psi), E=10E6 (psi), D=4100 (mm), L=7600(mm), Eq. 8 and 9 gives a relation between total thickness of honeycomb and its core thickness (or its skin thickness) shown in Figure 3 with a KF(knockdown factor) =1, and Figure 4 with a KF= 0.75. It is found that the CGA and Roark's equation give a same result. Furthermore, If we assume the total thickness of honeycomb structure to be 46 (mm), the curve gives an effective thickness 4 (mm) for KF=1, and 5.11 (mm) for KF=0.75, which are same as the Japanese calculation.

REFERENCES:

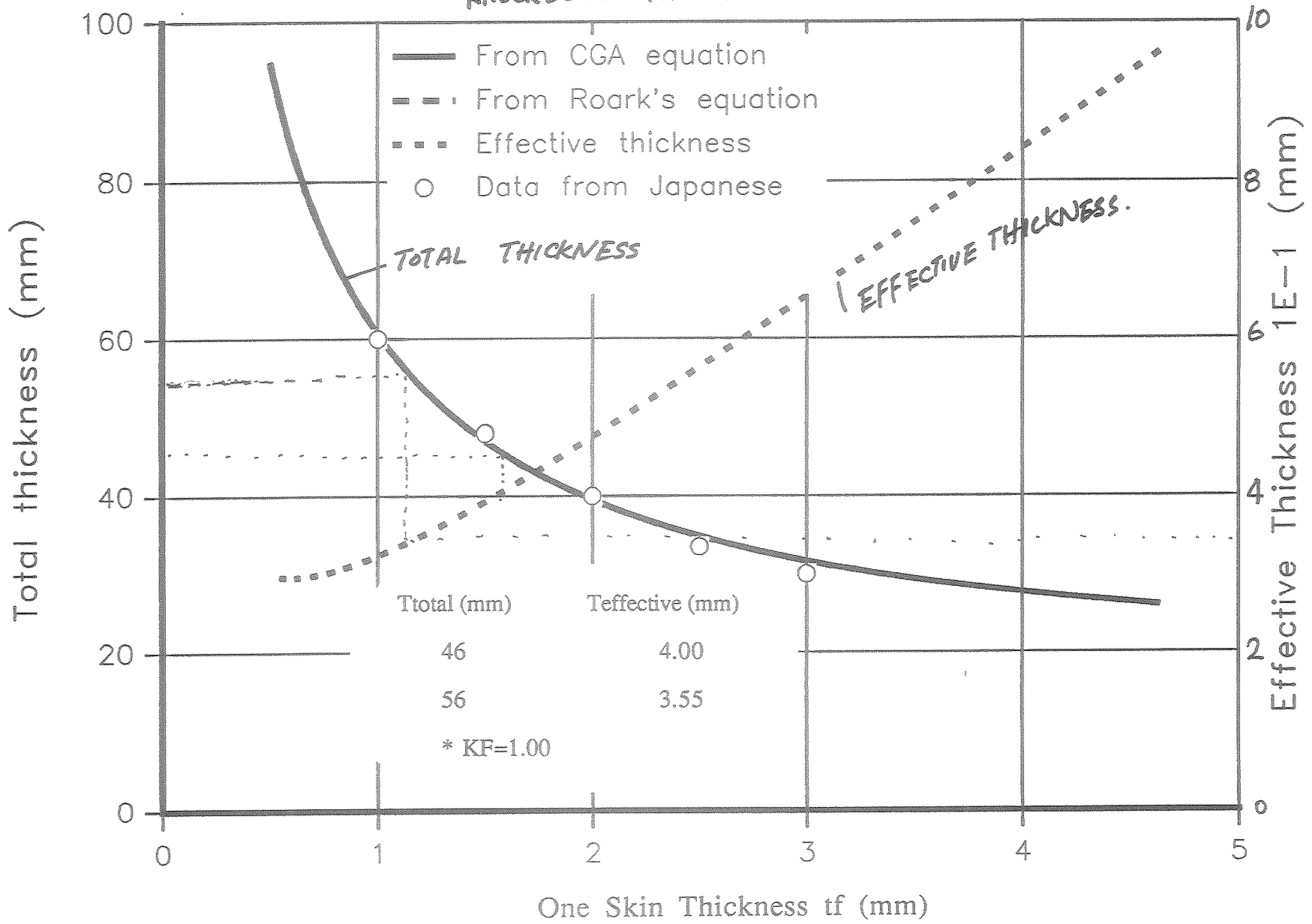
1. J.H. Faupel, F.E.Fisher , " Engineering Design", Wiley-Interscience, 1981, pp 320-325
2. Ron Fast , "CGA Equation for Homogeneous Outer Vacuum Shells; Shell Thickness For Typical Material", SDC DN-126, Dec. 20, 1990
3. W.C. Young, " Roark's Formulas For Stress and Strain", Sixth Edition, McGraw-Hill, 1989, pp 690
4. L.W. Swenson, " Bulking and Stress Analysis of the SDC (Isogrid) Vacuum Shell", SDC. DN-156, Aug 30,1991, pp 7

FIGURE 3

The total thickness of honeycomb as function of facing thickness

P collapse 30 psi, Core Size: 3/16 HEX, 1 mil thick

KNOCK DOWN FACTOR KF=1



Ttotal (mm)	Teffective (mm)
46	4.00
56	3.55

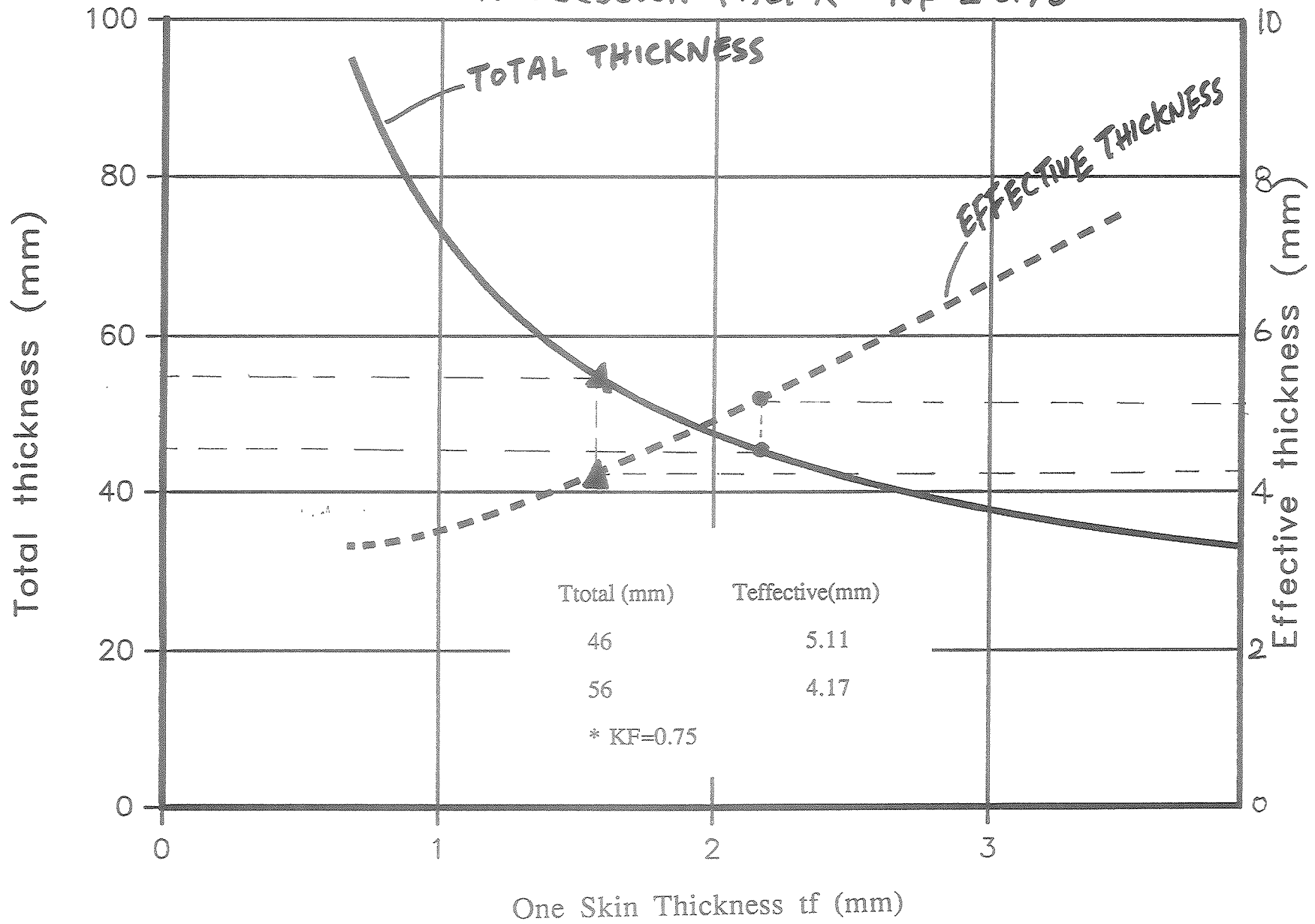
* KF=1.00

FIGURE 4

Total thickness of honeycomb as a function of the skin thickness

P cllapse 30 psi; core size 3/16"; 1 mil thick

KNOCKDOWN FACTOR KF = 0.75



Ttotal (mm)	Teffective(mm)
46	5.11
56	4.17

* KF=0.75